Fermilab FERMILAB-Conf-00/132-E June 2000

# LEPTOQUARK SEARCHES AT THE TEVATRON

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We report on searches for leptoquarks using approximately 100 pb$^{-1}$ of data collected by CDF and DØ during Run I at the Tevatron. We also present searches for resonantly-produced leptoquarks that arise in technicolor models. Prospects for future leptoquark searches using Run II data are also discussed.

## 1 Introduction

Leptoquarks are hypothetical bosons that carry both lepton and baryon number and that arise in many extensions of the Standard Model. They may be produced in pairs in $p\overline{p}$ collisions with a cross section essentially independent of the Yukawa coupling to a lepton and quark. The branching fraction to a charged lepton, denoted by $\beta$, is model-dependent.

Searches for the pair production of first, second and third generation leptoquarks by the CDF and DØ experiments—using data collected during Run I at the Tevatron at $\sqrt{s} = 1.8$ TeV—are described briefly in the following sections. Since no evidence for leptoquark production has been observed, CDF and DØ have set 95% CL upper limits on the production cross section for various leptoquarks and translated these limits into lower limits on leptoquark mass using the NLO theoretical prediction [1] for scalar leptoquarks and the LO predictions for vector leptoquarks with Yang-Mills and minimal vector couplings. These mass limits are summarized in Table 1 rather than included in the text.

## 2 First Generation Limits

CDF has published results [2] on the $eeqq$ signature using 110 pb$^{-1}$ of data, whereas DØ has searched [3] for $eeqq$, $e\nu qq$, and $\nu\nu qq$ using 123, 115, and 7.4 pb$^{-1}$ respectively. The selection requirements for all three signatures, in general, are that electrons must have $E_T > 20$–25 GeV, jets must have $E_T > 15$–30 GeV, and neutrinos are inferred from $\not\!\!E_T > 30$–40 GeV. Principal backgrounds arise from Drell-Yan production of electrons (plus jets) for the $eeqq$ channel, as well as $W$, $Z$, and top production for the other channels. The observations made by both experiments are consistent with background expectations.

Table 1: Leptoquark lower mass limits (GeV/$c^2$) from the Tevatron at the 95% CL.

| $\beta$ | Scalar | Yang-Mills | Minimal Vector | Comments |
|---|---|---|---|---|
| First Generation | | | | |
| 1 | 242 | – | – | Combined CDF/DØ |
| 1 | 213 | – | – | CDF $eeqq$ channel |
| 1 | 225 | 340 | 290 | DØ $eeqq$ channel |
| 1/2 | 204 | 325 | 275 | DØ combined |
| 0 | 79 | 200 | 145 | DØ $\nu\nu qq$ channel |
| Second Generation | | | | |
| 1 | 202 | – | – | CDF $\mu\mu qq$ channel |
| 1/2 | 160 | – | – | CDF $\mu\mu qq$ channel |
| 0 | 123 | 222 | 171 | CDF $\nu\nu cc$ channel |
| 1 | 200 | 325 | 275 | DØ $\mu\mu qq$ channel |
| 1/2 | 180 | 310 | 260 | DØ combined |
| 0 | 79 | 205 | 160 | DØ $\nu\nu qq$ channel |
| Third Generation | | | | |
| 1 | 99 | 225 | 170 | CDF $\tau\tau bb$ channel |
| 0 | 148 | 250 | 199 | CDF $\nu\nu bb$ channel |
| 0 | 94 | 216 | 148 | DØ $\nu\nu bb$ channel |

## 3 Second and Third Generation Limits

Both the CDF and DØ experiments have searched for second and third generation leptoquarks by tagging muons and taus in the final state [4–7]. Of these, we describe here only the DØ search for second generation leptoquarks in the $\mu\mu qq$ and $\mu\nu qq$ channels [6]. The single muon (dimuon) analysis requires muons with $p_T > 25$ (20) GeV. Two jets with $E_T > 15$ (20) GeV are required. A cut on the event sphericity in the c.o.m. of all jets and muons is applied in the dimuon search, whereas $\not{E}_T > 30$ GeV is required in the single muon analysis. In both searches, neural networks are applied for the final selection using the kinematic information from the muons, jets, and $\not{E}_T$. No leptoquark candidates survive. The final exclusion in the $\beta$ vs. mass plane is shown in Fig. 1.

In contrast to these searches sensitive to $\beta > 0$, CDF has searched [8] for second and third generation leptoquarks which decay to $\nu c$ and $\nu b$, respectively, by identifying heavy-flavor jets with a measurable lifetime in the silicon vertex detector. The principal selection requirement is $\not{E}_T > 40$ GeV. Two or three jets in the event with $E_T > 15$ GeV and $|\eta| < 2$ are required . A lepton veto is applied. The primary background is the production of $W$+jets.

A cut on the "jet probability" [9] is applied to tag $c$- and $b$-jets. The jet probability is constructed from the probabilities of individual tracks in the jet to have originated from the primary collision vertex, using the impact

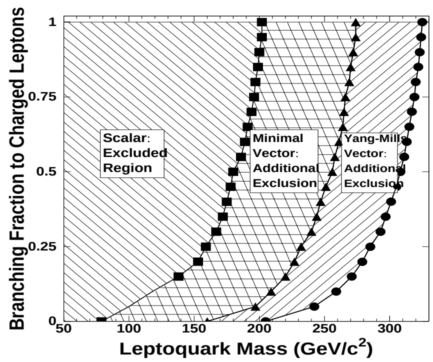


Figure 1: DØ exclusion of $\beta$ vs. second generation leptoquark mass at 95% CL.

parameter and its resolution measured by the CDF silicon vertex detector. Jets without a heavy-flavor component have a jet probability which is flat from 0 to 1, whereas $c$- and $b$-jets have a jet probability that peaks at 0. For second (third) generation leptoquarks, the jet probability cut is $\mathcal{P} < 5\%$ ($\mathcal{P} < 1\%$), which selects 11 (5) events in 88 pb$^{-1}$ of data compared to a background expectation of $14.5 \pm 4.2$ ($5.8 \pm 1.8$) events. Limits on the production cross section are shown in Fig. 2.

## 4 Resonantly Produced Leptoquarks

Leptoquark pair production could be enhanced from the decay of technicolor resonances. One formulation of technicolor [10] provides a rich spectrum of technirhos ($\rho_T$) and technipions ($\pi_T$) starting from an isodoublet of color triplet techniquarks and an isodoublet of color singlet technileptons. The color octet $\rho_T$s have the same quantum numbers as the gluon, and thus may be produced through the $s$-channel in $p\overline{p}$ collisions. The $\rho_T$ decays into two $\pi_T$s (some of which are color triplets), which in turn decay preferentially into heavy flavors. Thus, the null result of the second and third generation leptoquark search [8] constrains this technicolor model. Figure 2 shows the 95% CL exclusion of the $\pi_T$ mass vs. $\rho_T$ mass for $\pi_T \to \nu b$ decays. The exclusion depends somewhat on the mass splitting ($\Delta M$) between the color octet and triplet $\pi_T$s.

## 5 Future Prospects

Run II at the Tevatron is scheduled to begin March, 2001. Within the first two years of operation, an integrated luminosity of 2 fb$^{-1}$ is expected to be delivered at an increased center-of-mass energy of 2 TeV. By the time the LHC

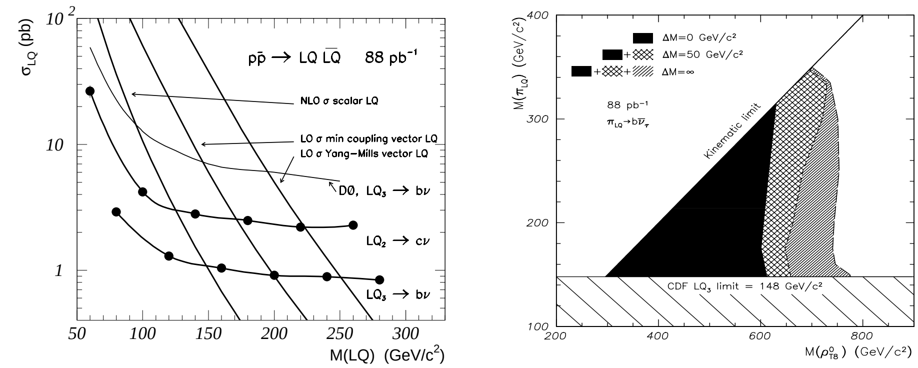


Figure 2: Left: CDF upper limits at the 95% CL on the production cross section for $LQ_2 \to \nu_\mu c$ and $LQ_3 \to \nu_\tau b$ along with the theoretical predictions for $\beta = 0$. Right: CDF 95% CL exclusion regions in the $\pi_T$ mass vs. $\rho_T$ mass plane for $\pi_T \to \nu b$ decays.

begins operation, the Tevatron may have delivered a total of 30 fb$^{-1}$.

If we assume that first-generation leptoquarks are not discovered and no events are observed at high mass, then the Tevatron experiments should be able to set a lower limit [11] on the scalar leptoquark mass of approximately 300 GeV/$c^2$ (375 GeV/$c^2$) for 1 fb$^{-1}$ (10 fb$^{-1}$) of data and for $\beta = 1$. For the case of scalar leptoquarks of the third-generation with $\beta = 0$, limits should improve to 220 GeV/$c^2$ with 2 fb$^{-1}$ of data. Likewise, limits on the color-octet $\rho_T$ should improve to about 1 TeV/$c^2$, depending on the $\pi_T$ mass splitting.

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